

Motivation and Scientific Objectives

The Challenge of QCD

The twentieth century has been an era of striking progress in understanding the fundamental structure of matter:

- Quantum mechanics and atomic physics
- Nuclear physics
- Standard Model of elementary particle physics

However, the traditional analytic tools to calculate atomic and nuclear systems are inadequate to solve QCD - the component of the Standard Model describing strong interactions.

Our understanding of Nature will remain fundamentally deficient until we know how the rich and complex structure of strongly interacting matter, which comprises most of known mass of the universe, arises from the interactions among quarks and gluons.

Lattice QCD

Having reached the limits of analytical methods, theoretical physicists have invented a new approach:

Monte Carlo evaluation of the QCD path integral on a discrete space-time lattice

Features:

- Solution of QCD from first principles
- Controlled systematic errors
- Well established and tested
- Theorists have extensive experience and expertise in high performance computation:
 - performance optimization
 - algorithms

Terascale computation will have decisive impact:

- Determine precisely the parameters on the Standard Model and thereby facilitate the search for new physics beyond it.
- Discover the properties of hadronic matter under extreme conditions in the laboratory and in the cosmos.
- Understand from first principles the structure of nucleons and other hadrons.

Our national collaboration brings the expertise and manpower required to aggressively utilize terascale computing resources to solve this broad range of fundamental problems.

Urgent need for terascale lattice calculations

The U.S. has invested heavily in a new generation of experimental facilities to explore the frontiers of nuclear and particle physics.

Terascale lattice QCD calculations must be undertaken now to realize these facilities' full potential.

The incremental cost is a small fraction of the facility cost.

- Tests and Parameters of the Standard Model

The B-factory at SLAC and the CESR storage ring at Cornell will measure matrix elements between hadrons, but one must solve QCD on a lattice to obtain the underlying fundamental matrix elements between quarks

- The Phases of QCD

The primary goal of RHIC at BNL is to observe a new state of matter, the quark-gluon plasma, but lattice QCD is the only way to calculate the properties of the phase transition and the equation of state which are needed to interpret the experiments.

- Hadron Structure and Spectroscopy

The CEBAF accelerator at Jefferson Lab, the Bates accelerator, and the RHIC spin experiments will provide precision probes of the structure of hadrons which can only be calculated theoretically by solving QCD on a lattice.